

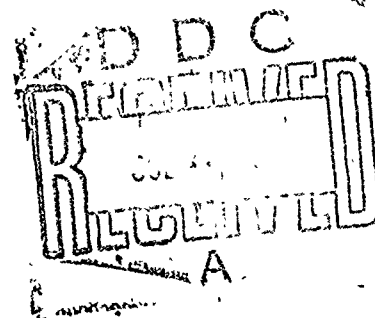
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MINISTRY OF AVIATION SUPPLY

**EXPLOSIVES RESEARCH
AND DEVELOPMENT ESTABLISHMENT**

TECHNICAL REPORT No. 45

**Compatibility and Stability Testing of
Explosives and Solid Propellants****N J Blay
I Dunstan****WALTHAM ABBEY
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Compatibility and Stability Testing of
Explosives and Solid Propellants

by

N J Blay
I Dunstan

SUMMARY

This Report, the text of a lecture given at a Symposium on Military Explosives Research (Holland; September, 1969), is a general account of the main principles involved in the compatibility and stability testing of explosives, pyrotechnics, and solid propellants. Chief emphasis is given to laboratory methods of assessment based on observation of chemical change occurring under accelerated ageing conditions, but mention is also made of physical factors such as exudation and migration of ingredients, and the effect of explosives and propellants on the mechanical properties of polymers, rubbers, and other structural materials.

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FOREWORD

This Report is the text of a lecture delivered at a Symposium: "Research on Military Explosives and Ammunition", 26 September 1969, organised by the National Defence Research Organisation of the Netherlands. The Proceedings of the Symposium have been published and a copy is held by the Library Services of ERDE.

INTRODUCTION

This paper is confined to considerations of compatibility and stability problems encountered in the design and development of weapon systems containing explosives and solid propellants. Corresponding problems associated with the manufacture and use of liquid and hybrid propellants will not be mentioned; these are well covered in papers presented at a recent meeting of the American Chemical Society (Miami Beach, 1967).

The primary objectives of compatibility and stability testing are to ensure safety during storage and reliability in service, by assessing the chemical and thermal stability of explosive and propellant compositions, and by determining whether these properties are adversely affected by any of the materials used near or in contact with them. The problem is complicated not only by the frequent necessity to meet stringent storage and service requirements, but also by the increasing complexity of the compositions being developed, particularly in the propellants field, and by the wide range of non-explosive materials used in the construction of weapon systems.

Some idea of the scope of this work may be gained by reference to the diagram of a hypothetical guided weapon shown in Fig. 1. In such a weapon the warhead might be filled with a charge based on one or more secondary high explosives, and various initiating compounds or compositions would be used to fill detonators in the safety and arming unit and in the nose release device. As well as establishing the stability and mutual compatibility of the ingredients of the separate fillings, it is also necessary to study their compatibility with interior surface coatings, sealants, lutings and potting compositions used in the assemblies, and to ensure that the explosives are not adversely affected by any of the numerous materials which surround them. Conversely, it is of importance to determine whether the explosives themselves are likely to affect structural components in their vicinity - as occurs for example, when corrosion of metal parts is observed.

Questions regarding stability and chemical reactivity apply equally to the propellant charges, particularly those based on nitrate ester compositions. The inherent instability of nitrate esters is well known, and colloidal propellants are subjected to all kinds of ageing studies in attempts to predict service life and to devise satisfactory surveillance procedures. These stability studies are usually supported by compatibility investigations to check the suitability of novel ingredients, and to investigate possible interactions between the propellant and inhibitors or adhesives used in contact with it. Interaction may be of a chemical nature or may arise as a result of migration and interchange of soluble compounds such as plasticisers or nitrate esters.

Choice of materials for the igniter assembly and match-head fuse shown schematically in Fig 1 is also dictated at least in part by stability and compatibility requirements. Operational reliability may be critically dependent upon the extent to which the pyrotechnic compositions remain stable, and the seals and plastic components resist attack by nitroglycerine or other volatile components of the propellant motor.

Compatibility testing and specification control is frequently extended to include the various paints, lacquers and protective finishes which are used in the guided weapon - not only to determine storage characteristics, but also as a safeguard should accidental contamination of explosives or propellants occur during assembly.

There is no difficulty in detecting extreme incompatibility between explosives and materials. Even the simplest tests provide sufficient evidence to justify rejection. However, many stability and compatibility problems which face designers and manufacturers are much more subtle, and recommendations for acceptance or rejection require careful experimentation and interpretation backed by skilled judgement. Among the more frequent causes for rejection are interactions which reduce the chemical stability of the explosive or enhance its sensitivity to ignition by heat, friction, mechanical shock, or electrostatic discharge; rejection of non-explosive substances may often be due to failure in the material itself following exposure to explosives or propellants.

In the following sections of this paper an attempt is made to describe those characteristics of explosives and propellants which have a bearing on their stability and compatibility behaviour, and some of the more useful test methods are discussed. The sections are arranged according to specific compound-types or compositions.

HIGH EXPLOSIVES

Most high explosives used for military purposes are based on solid, nitro-containing compounds such as TNT (nitroaromatic), RDX (nitramine), and PLTN (nitrate ester). In general these compounds possess excellent thermal stability at temperatures below their melting points, but show a marked decrease in stability in the molten state.

The low melting point of TNT (ca 80°C) is certainly advantageous as far as mixing and filling operations are concerned - steam-heating suffices for most purposes - but this characteristic property sometimes leads to the formation of low melting eutectics between the explosive and polymer ingredients such as plasticisers. Moreover, TNT has a tendency to migrate into rubbers and polymers, often causing severe physical deterioration. Trials performed at ERDE on the effect of heating thermoplastics and rubbers with TNT at 60°C (Fig 2) show that most of the materials suffer losses in tensile strength compared with control samples heated in the absence of explosive. In contrast, tetryl (CE) is almost without effect on the materials listed.

The chemical behaviour of the common high explosives is well documented. Acids, alkalies, organic bases and strong oxidising or reducing agents are generally incompatible. Ammonium nitrate, a major constituent of amatol explosives, is particularly vulnerable to carbonyl compounds and to alkaline contaminants. The former tends to produce acidity, and the latter may release ammonia, a compound which is severely incompatible with TNT. As a rule it is inadvisable to allow high explosives to come into contact with substances of an alkaline nature - in extreme cases highly sensitive reaction products may be formed with a consequent increase in the chance of accidental ignition.

In the UK, acceptance and compatibility tests on high explosives usually include the vacuum stability test. This is an empirical heat test in which rate of gas evolution is measured under isothermal conditions (Fig 3). Limits of ca 1 cc of gas per gram of sample are set for samples heated at 120°C (150°C for RDX) for 40 hr (25 hr for PETN). Somewhat lower test temperatures are used to assess compatibility.

The vacuum stability test has the merits of convenience and simplicity, although it should be recognized that there are inherent disadvantages in the method which may result in misleading information. For example, gas pressures generated by solvents, foam blowing agents and volatile plasticisers may invalidate the results. Moreover, any contamination which lowers the melting point of the explosive may have quite disproportionate effects on its apparent stability, because decomposition and gassing occur much more rapidly when the substrate has a liquid phase.

The results of compatibility trials shown in Fig 4 are selected from an extensive library of test data which includes all kinds of sealants, putties, structural materials and commercial products used in the manufacture and packaging of explosive items.

INITIATORY EXPLOSIVES

A characteristic property of initiatory explosives is the ease with which such compounds are detonated by mild, relatively low-energy stimuli (heat, friction, impact, electrostatic discharge, etc), and it is self-evident that care must be taken at all stages of manufacture, filling and storage to ensure that this sensitivity is not further increased by contamination, or by an ill-advised choice of ingredient or structural material. Potential reasons for increased hazard include: accidental contamination with gritty substances, formation of highly sensitive corrosion products (copper azide is perhaps the best known), and generation of high electrostatic charges on materials such as synthetic polymers.

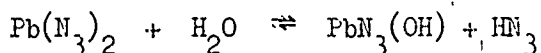
In designing detonators for military use it is generally regarded as essential that the store shall remain safe and efficient for a number of years. Care is taken to assess the chemical stability of the initiatory ingredients under dry and moist conditions and at temperatures well above those likely to be encountered in normal service environments. Appropriate compatibility and corrosion tests are performed on all non-explosive and metallic components.

Most of the commonly used initiatory explosives possess adequate thermal stability for general purposes, although some degradation might be expected to occur if the compounds are exposed to moisture or to other reactive vapours. Sealing with a compatible varnish often provides sufficient protection against such attack, but the tendency for "breathing" to occur due to temperature cycling may defeat an inadequate or imperfect seal. In this connection it is worth noting that the free space in any closed or poorly ventilated assembly which contains, or is constructed from, plastics, rubbers and other synthetic materials may be heavily contaminated with the vapour of low molecular weight organic compounds. Typical examples of such contaminants, detected by vapour phase chromatography (V), mass

spectrometry (M), and Dräger tube (D), are shown in Fig 5, together with some possible sources.

Useful illustrations of the points which have been made regarding the effect of storage conditions and environment on chemical stability are provided by considering the chemistry of lead azide. Although this compound has several modes of decomposition (Fig 6), published data indicate that deterioration due to thermal instability can be discounted at ordinary temperatures. However it is well-known that lead azide is susceptible to attack by water. Indeed the reaction forms the basis of the "copper strip compatibility test", a simple screening procedure in which the material under investigation is placed in contact with moist lead azide, and the rate of formation of hydrazoic acid is monitored by observing its effect on a strip of copper held above the mixture. This test is intended to give early warning of the likelihood of "azide corrosion" - the formation of copper azides - very sensitive salts produced by the action of hydrazoic acid on copper or brass components. Some protection is afforded, by tin- or silver-plating the metals.

Results of more detailed studies on the stability of lead azide are summarised in Fig 7. These show that a combination of high test temperature (80°C) and high relative humidity is necessary to achieve any substantial decrease in azide content. It is significant however, that the extent to which degradation occurs is considerably enhanced when the tests are conducted in a larger vessel, in an atmosphere of carbon dioxide, or over an alkaline absorbent. These observations are best interpreted by assuming that the initial step in the hydrolysis may be represented as a reversible equilibrium:



and consequently those physical or chemical factors which shift the equilibrium to the right will favour azide degradation. In other words, any process which leads to the removal of hydrazoic acid or basic lead azide from the system will tend to accelerate the irreversible decomposition of lead azide. The implications of these findings and the restrictions they place upon the materials to be used in the vicinity of the initiator are clear.

PYROTECHNICS

Most pyrotechnics consist of intimate mixtures of fuels, typically metals such as magnesium, aluminium or zinc, and oxidizers, for example, salts of nitric or perchloric acids; additional ingredients may be used to modify performance or to improve filling or stability characteristics. The separate ingredients of pyrotechnics are generally stable, and storage problems affecting the final product are usually attributable to interaction with moisture or reactive vapours from plastics, rubbers, etc.

Moisture is particularly troublesome when free metals are used in the pyrotechnic composition. Its presence may cause corrosion of the metal, with consequent deterioration in performance, or gas evolution, and an increase in pressure if the mixture is in a sealed container. Coating the metal with a suitable oil or

resin - the usual practice with a reactive ingredient such as magnesium - affords some degree of protection against moisture, although it is unlikely to be effective for prolonged storage under humid conditions.

In considering the choice of material to be used near or in contact with pyrotechnics it is worthwhile taking into account not only the extent to which the substance is likely to generate moisture or other reactive vapours, but also the actual amount of material it is proposed to use. Even low levels of moisture or reactive vapour may be intolerable if their source is massive in relation to the size of the pyrotechnic charge. This "mass action" effect may be even more pronounced if the pyrotechnic contains salts which act as desiccants, or strong, reactive oxidants (chromates, dichromates, lead peroxide, etc) which oxidize organic vapours.

Incompatibility arising from direct contact between pyrotechnics and materials such as rubbers and plastics under dry conditions is rare, although absence of chemical interaction does not necessarily preclude the risk of increased sensitiveness if the material is gritty or contains ingredients which sensitise the pyrotechnic; for example, sulphur may enhance the sensitiveness of an explosive containing a chlorate salt.

Compatibility test methods depend upon the nature of the pyrotechnic and its intended application. Materials proposed for use in direct contact with the charge are usually tested in admixture with the explosive at elevated temperatures, but not often in excess of 100°C. Visual observation may be supported by thermogravimetric analysis of the mixture and chemical analysis of residual explosive; evolution of gases, including hydrogen, is conveniently measured by vacuum stability tests.

Proximity tests, in which small samples of pyrotechnic are heated with a relatively large mass of the material under investigation give useful information on the effects of vapour on the composition. Appropriate chemical or physico-chemical methods are used to assess the extent to which the explosive deteriorates after a suitable period of heating.

Some of the better known examples of substances incompatible with pyrotechnic ingredients are listed in Fig 8.

COLLOIDAL PROPELLANTS

Colloidal propellants are based on nitrocellulose (single-base), often with nitroglycerine as the second principal ingredient (double-base). Formulations may also include stabilisers, plasticisers, coolants, and ballistic modifiers, as well as oxidizers, fuels, and other explosive ingredients such as nitroguanidine (picrite), dinitrotoluene, ammonium perchlorate and aluminium powder.

It is a characteristic property of all colloidal propellants that the nitrate ester constituents, particularly nitroglycerine, undergo slow, but autocatalytic decomposition even at ambient temperatures. Products of decomposition (nitrogen dioxide, nitrous and nitric acids) are absorbed by incorporating stabilising

compounds in the propellant; these have the dual function of preventing autocatalytic acceleration of the rate of decomposition, and of reducing the risk of ignition by self-heating - a risk which can be regarded as significant only in relatively large masses of propellant. Removal of gaseous decomposition products is particularly desirable in rocket propellants - failure to do so may lead to cracking and malfunction.

Tests used to assess the compatibility and stability of colloidal propellants are primarily concerned with predicting the safe chemical life of the charge under normal storage conditions. In the UK such assessments are generally based on the results of the Silvered Vessel Test and on stabiliser consumption trials.

In the Silvered Vessel Test we measure the tendency of a standard propellant to undergo self-heating when ground up, mixed with the test material, and heated at 80°C in a spherical Dewar vessel (Fig 9). A simple double-base propellant with a test time of ca 600 hr is used as a substrate for compatibility tests, and materials are pronounced free from hazard provided the test time exceeds 400 hr (Fig 10). However, it is important to note that satisfactory performance in this test may not necessarily be equated with acceptable compatibility. For example, quite reactive systems may give extended, but misleading, test times if the material contains an ingredient which functions as a propellant stabiliser. Another major shortcoming of the test is that it is usually based on a non-service propellant composition, rather than on service propellants. If the latter were to be used test times would be excessively long, and the end of the test might be marked by violent decomposition if the composition were particularly energetic.

More reliable information is obtained by measuring rates of stabiliser consumption when propellants are subjected to accelerated ageing, alone and in contact with the test material. Accurate methods of analysis, for example, thin layer chromatography, are required to monitor the stabiliser concentrations, but such trials have the advantages that the types of propellant and the experimental conditions can be chosen with more regard to the actual requirements for the test material and the circumstances in which it is to be used. Results for some well-known cordites stabilised with diphenylamine or carbamate are shown in Fig 11. Predicted safe lives are calculated on the assumption that the rate of deterioration of propellants increases ca 1.3 times with every 10°F rise in temperature; safe storage life is arbitrarily taken as the time to half-stabiliser for carbamate-stabilised propellants.

Although carbamate is an effective stabiliser for colloidal propellants its reaction with nitrate ester decomposition products often produces gases which are not absorbed by the propellant matrix. Cracking may occur if these gases are evolved at such a rate that they are unable to escape by diffusion through the charge. Laboratory investigations of gas formation have shown that the nature and amount of the gaseous products depend not only upon the composition of the propellant but also upon whether the test is performed in the presence or absence of oxygen. These experiments are conveniently monitored using the technique of gas-liquid chromatography; its value is illustrated by the chromatograms shown in Fig 12.

Most colloidal propellants contain ingredients or contaminants which may exert a significant vapour pressure in air spaces around the charge. Water, solvents, triacetin and nitroglycerine are all sufficiently volatile to act as occasional sources of incompatibility. This may lead to physical deterioration of neighbouring materials, corrosion of metals, and even to chemical reaction with the ingredients of other explosives - for example, reaction with the oxidant in an adjacent pyrotechnic device.

Migration of ingredients is another phenomenon which sometimes causes practical difficulties. Exudation of liquids containing a high proportion of nitroglycerine is occasionally observed, and there is a great deal of evidence that the nitrate ester has deleterious effects on many rubbers and plastics (Fig 13). Conversely it is worth noting that nitrocellulose is readily plasticised by numerous plasticisers found in rubbers and plastics, and such materials are sometimes rapidly absorbed by propellants.

COMPOSITE PROPELLANTS

Composite solid propellants generally consist of an oxidizer, such as ammonium perchlorate or ammonium nitrate, an energetic metal such as aluminium, and an organic polymer which serves as both fuel and binder. Vacuum stability tests show that such compositions are intrinsically more stable than colloidal propellants, although attempts to use more exotic ingredients as oxidizers or fuels sometimes introduce severe compatibility problems.

The stability of conventional composite propellants is determined to a large extent by the chemical properties of the binder, but early evidence of deterioration often comes from observing changes in the mechanical properties of the charge, rather than from chemical investigations. This is because relatively small changes in the chemical nature of the binder, brought about, for example, by hydrolysis of polyurethane links or oxidation of hydrocarbon chains, may have a quite significant effect on the elastomeric characteristics of the propellant. Thermochemical techniques such as differential thermal analysis, have found limited application in studying cure chemistry and compatibility behaviour, and it seems likely that this approach may be used to an increasing extent as more sensitive calorimetric methods are developed.

Use of ammonium salts as oxidizers is common practice, and their stability and thermochemical properties, such as the occurrence of solid state phase changes, are well understood. Reference has already been made to the possible effects of carbonyl compounds and alkaline contaminants on ammonium salts, and the remarks are equally applicable to their use in composite propellants. With ammonium picrate, an important ingredient in some UK plastic propellants, there is the additional restriction that the weapon assembly should be free from lead-containing compounds likely to react with the ammonium salt to form lead picrate, a hazardous initiatory explosive.

FUTURE DEVELOPMENTS

Apart from the notable exception of stabiliser consumption trials, most of the test methods which have been mentioned in this paper depend upon observing the evolution of gas or heat during accelerated ageing trials on relatively small samples. These laboratory-type tests are invaluable as screening procedures on which to base decisions regarding more extended trials on larger amounts of explosive or on completed assemblies developed at a later stage of the design programme. There are clear advantages in carrying out relatively inexpensive, small-scale tests in view of the cost and possible hazards attending the type-testing of end-products. However, the tests suffer from several inherent disadvantages which sometimes limit their usefulness in predicting in-service safe life and serviceability. These arise from the two major extrapolations which have to be made in order to relate the results of such tests to the in-service behaviour of charges stored under ambient conditions. The extrapolations relate to the temperature difference between test and storage temperatures, which may amount to as much as 100°C, and the size factor - contrast, for example, the 70 grams of propellant used in the Silvered Vessel Test with a propellant grain weighing many hundreds of kilograms.

In principle it should be possible to go some way towards meeting these criticisms of present practice, and to extend the usefulness of stability testing by devoting more attention to the application of thermochemical methods to stability assessment. Thus, provided sufficiently sensitive methods of detection are available, the thermochemical approach should be capable of giving a very early indication of incipient chemical decomposition, possibly at very low test temperatures. Some progress has been made in this direction by using techniques such as differential thermal analysis (DTA) and differential scanning calorimetry (DSC), and a number of sophisticated commercial instruments have been developed. Typical DSC thermograms obtained from compatibility trials with a simple double-base propellant are shown in Fig 14. Although quite characteristic effects are observed in cases of extreme incompatibility, the technique is less discriminating than traditional methods, and there are obvious disadvantages in conducting this kind of measurement on only a few milligrams of material.

Significant progress towards improving thermochemical test methods, particularly with regard to exploiting more sensitive detection devices and using larger test samples, has been made during the past few years at the Technological Laboratory (RVO-TNO) in Delft. One of the most promising methods under development is that of heat flow calorimetry, a technique which enables measurements to be made of rates of heat generation from explosives or propellants undergoing slow thermal decomposition. This work, with its potential usefulness for investigating compatibility and stability problems, and self-heating hazards in large charges, is likely to attract a great deal of interest and attention in many explosives laboratories in future years.

CONCLUSIONS

This brief survey is intended to introduce the principles and practice of compatibility and stability testing, and to give some indication of the nature of the problems involved. The treatment of the subject is by no means comprehensive but it is hoped that sufficient has been said to persuade designers, manufacturers, and users of devices and weapon systems containing explosives that a systematic approach to the experimental assessment of compatibility and stability is well worthwhile. Needless to say, advice based on such assessments must be offered and received with caution. Apart from the obvious pitfalls of unrealistic test temperatures and unjustified extrapolation of test results from one explosive to another, it is apparent that erroneous conclusions may arise for more subtle reasons - for example, through performing tests on over-simplified systems or on unrepresentative proportions - and it is therefore essential constantly to review the choice of test conditions in relation to the in-service situation. Provided these limitations are recognized, the effort required to undertake this work is amply rewarded by the assurances such studies provide with regard to storage characteristics, safe-life, and operational reliability.

ACKNOWLEDGEMENTS

Results quoted in Figures 2, 5 and 13 were obtained by the Non-metallic Materials Branch of ERDE, and we are grateful to those concerned for permission to use the data. We are also glad to acknowledge the valuable assistance of J L McDougall, P G Packman, E F Pembridge and F I H Tunstall, members of the Compatibility and Stability Section at ERDE.

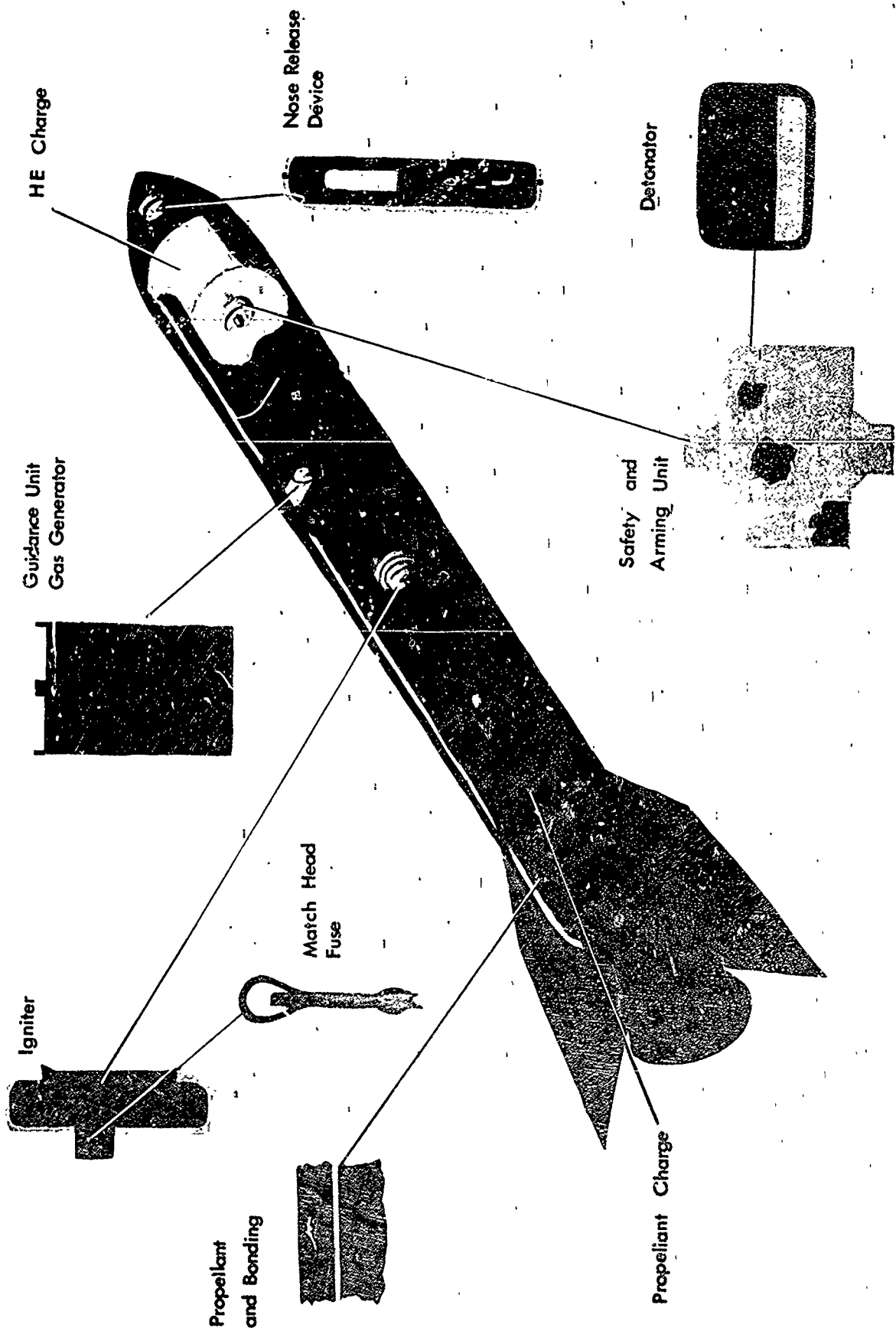


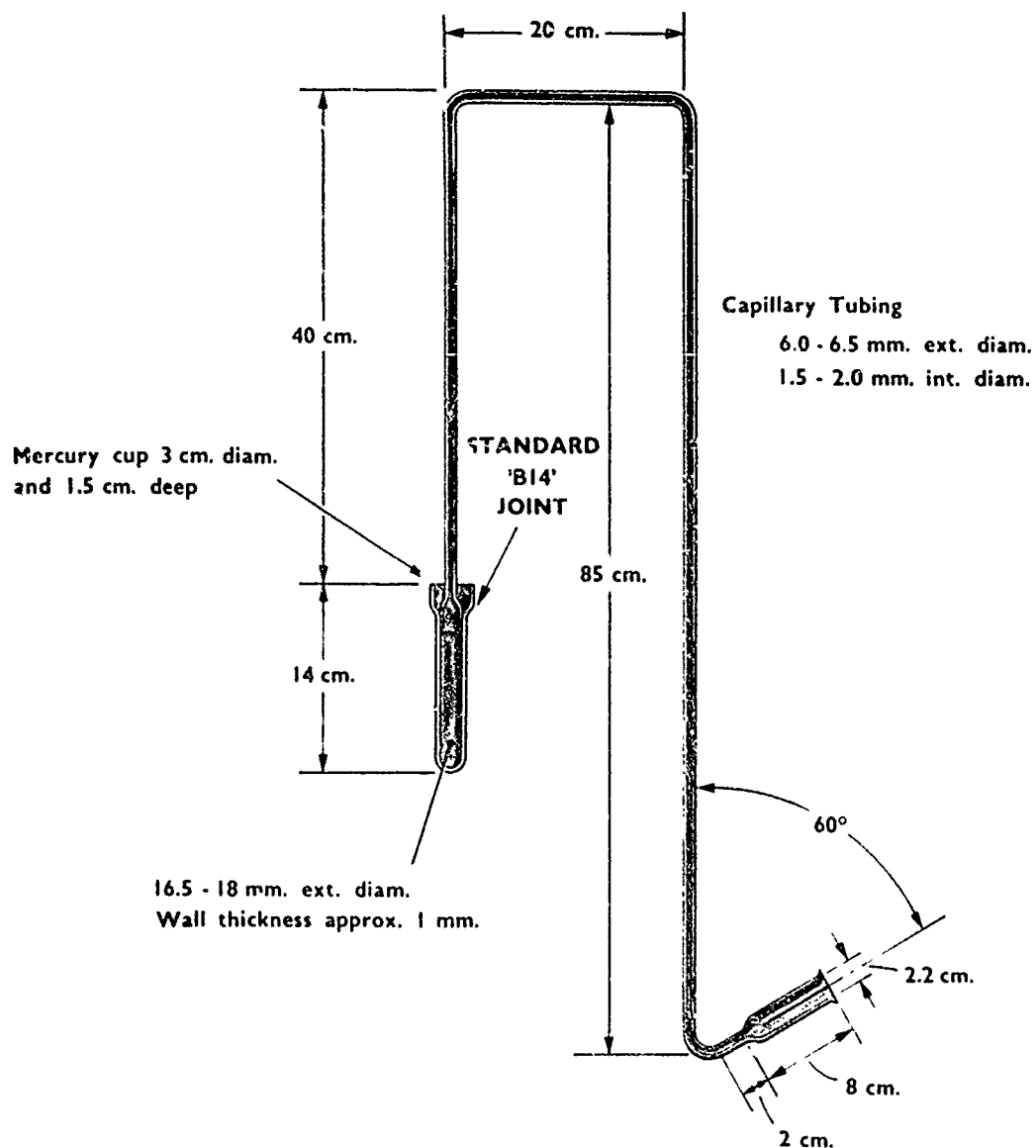
FIG. 1

EFFECT OF TNT AND CE ON THERMOPLASTICS AND RUBBERS

		DEGRADATION AFTER EXPOSURE AT 60°C FOR ONE YEAR		
		None to slight	Moderate	Severe
POLYMERS	POLYSTYRENE	TNT	TNT	
	ABS		TNT	
	STYRENE-ACRYLONITRILE			
	POLYPROPYLENE	TNT		
	NYLON 66	TNT,CE		
	POLYSULPHONE	CE	TNT	
	POLYCARBONATE			TNT
	POLYACETAL PVC	TNT		
RUBBERS	NATURAL			TNT
	NITRILE		CE	TNT
	NEOPRENE	CE		TNT
	BUTYL	TNT		
	SILICONE		TNT,CE	

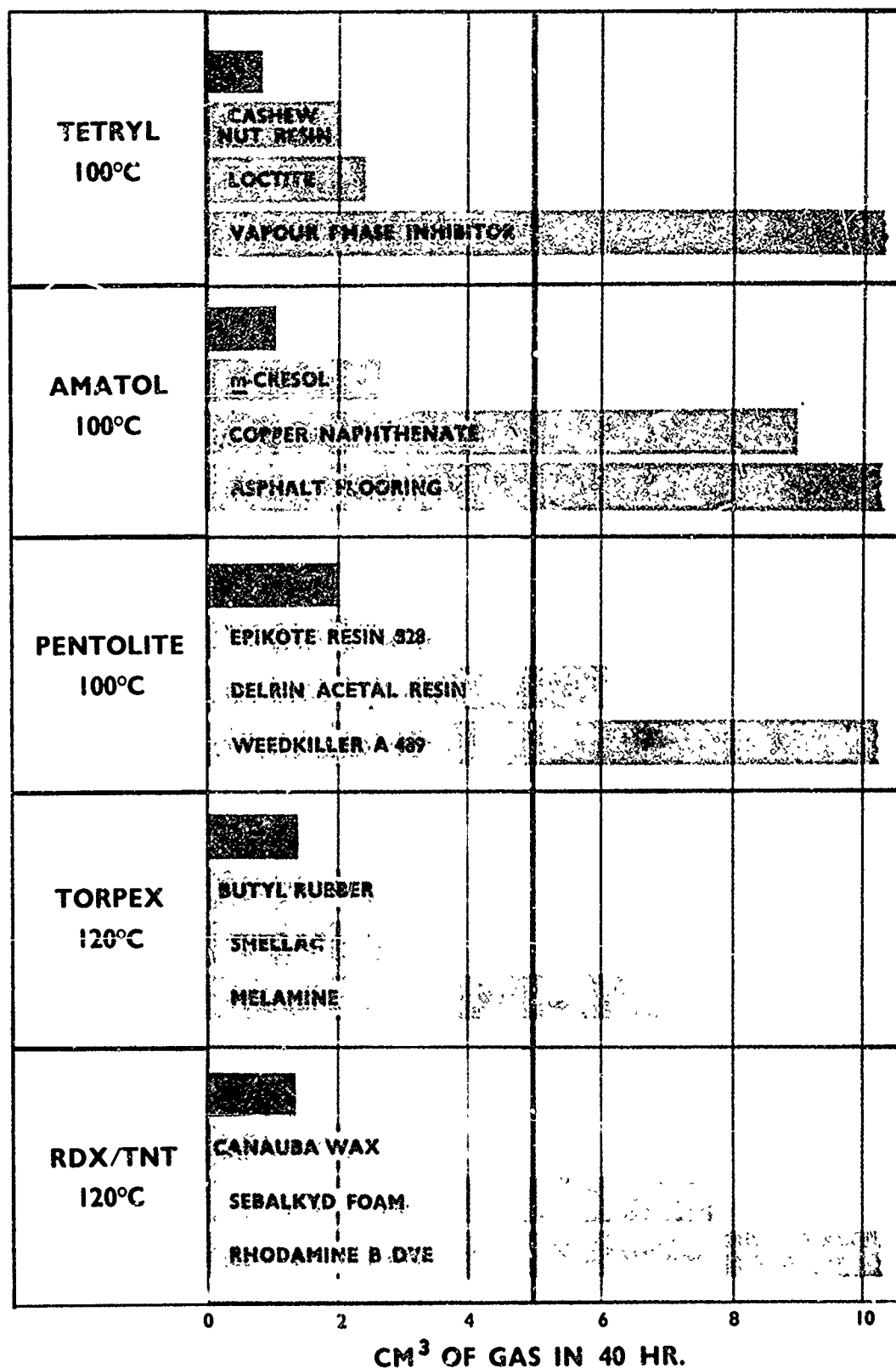
FIG. 2

VACUUM STABILITY TEST APPARATUS



The whole to be made of PYREX and the capillary to be uniform and as free from joins as possible

VACUUM STABILITY TEST - RESULTS

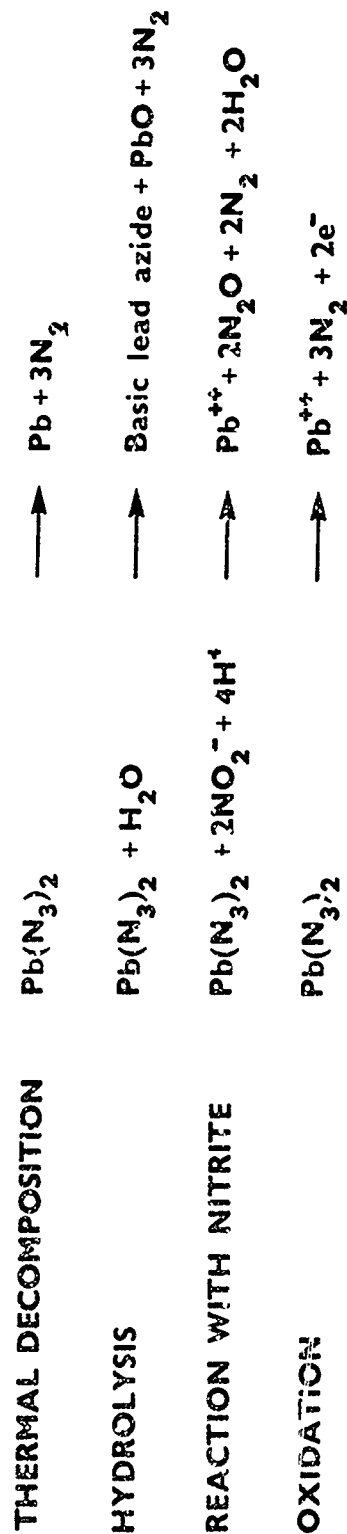


EVOLUTION OF GASES AND VAPOURS FROM COMMERCIAL MATERIALS

CONSTITUENT	METHOD OF DETECTION	POSSIBLE SOURCE
FORMALDEHYDE	D	THERMOSET (LAMINATE)
TRICHLOROFLUOROMETHANE	M	BLOWING AGENT (POLYURETHANE)
METHANOL	V	SOLVENT OR THINNER
ISOPROPANOL	M,V	SOLVENT OR THINNER
ISOBUTANOL	M,V	SOLVENT OR THINNER
METHYLISOBUTYLKETONE	M	SOLVENT OR THINNER
STYRENE	M	GR POLYESTER/STYRENE
PHENOL	V	THERMOSET (LAMINATE)
o-CRESOL	V	THERMOSET (LAMINATE)
p-CRESOL	V	THERMOSET (LAMINATE)

FIG. 5

MODES OF DECOMPOSITION OF LEAD AZIDE



METATHETICAL REACTIONS

FIG. 6

EFFECT OF HEAT AND MOISTURE ON LEAD AZIDE

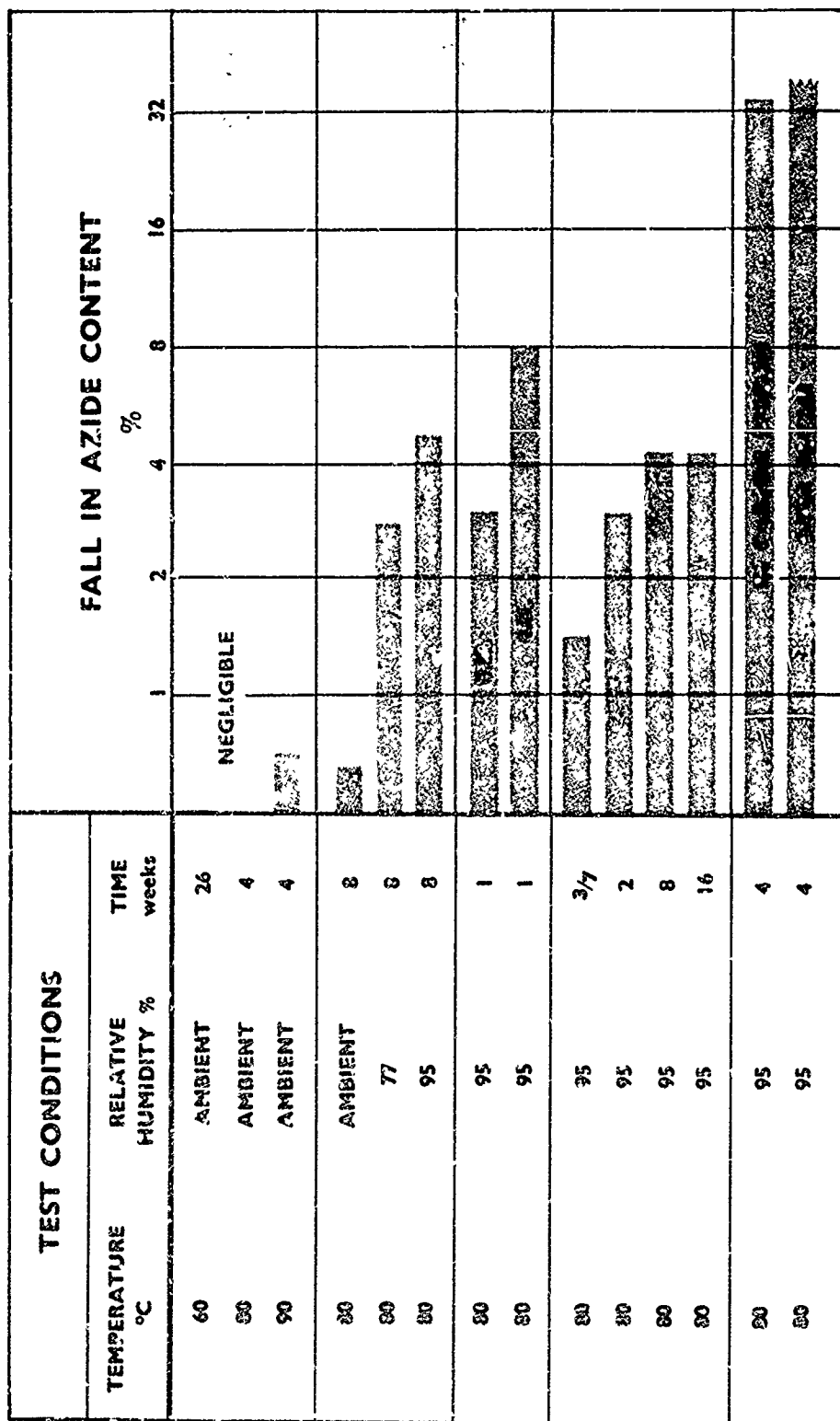


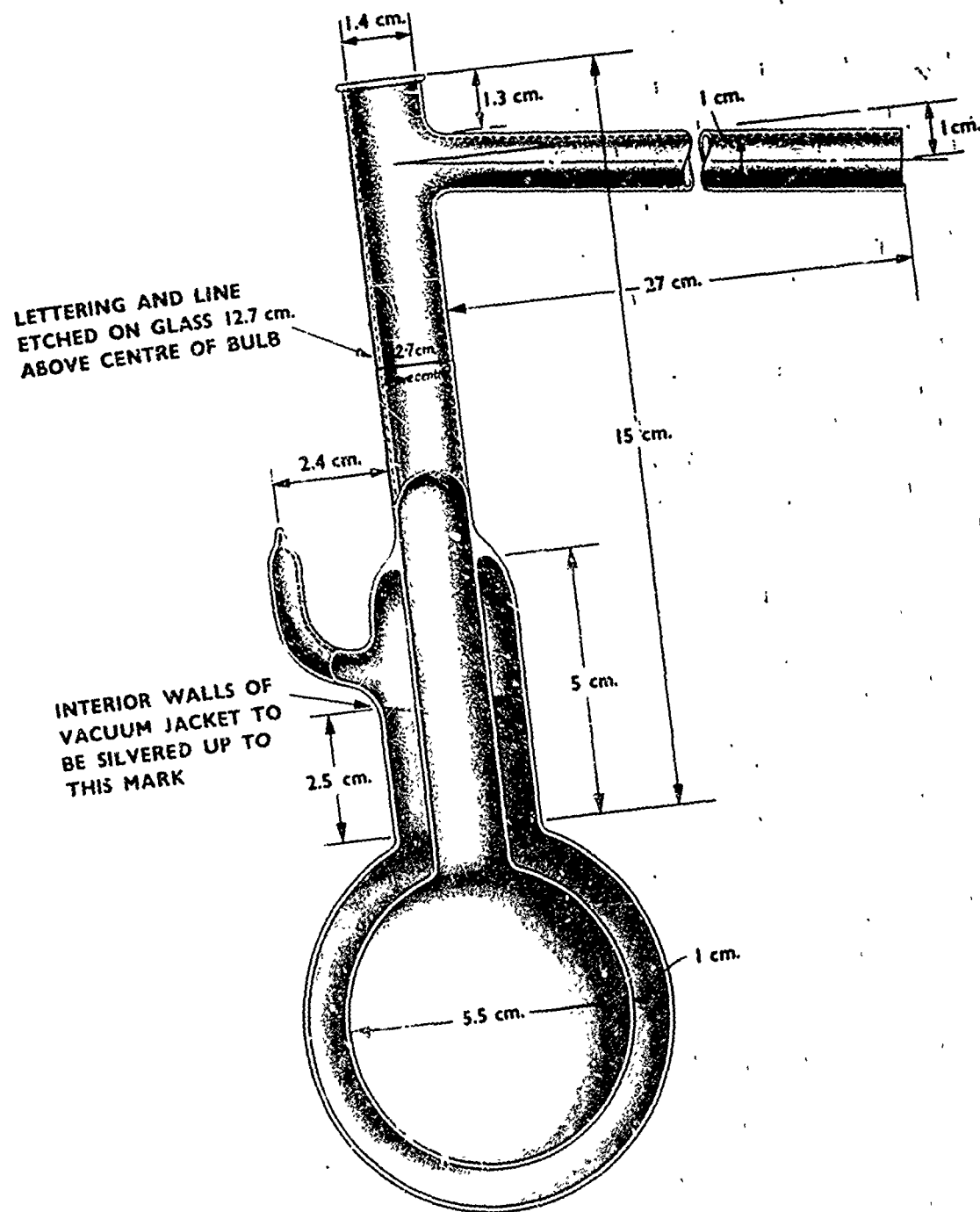
FIG. 7

PYROTECHNICS - VULNERABLE INGREDIENTS

INCOMPATIBLE SUBSTANCES	POSSIBLE SOURCE	VULNERABLE INGREDIENTS
Formaldehyde	Polyacetal and Phenolformaldehyde plastics	Oxidants (e.g. $K_2Cr_2O_7$)
Sulphur/Sulphides	Polysulphide plastics and rubbers	Magnesium; Chlorates
Acidic substances	Polyester plastics; PVA adhesives	Metals, especially uncoated magnesium
Alkaline substances		Aluminium
Water		Magnesium, Calcium silicide

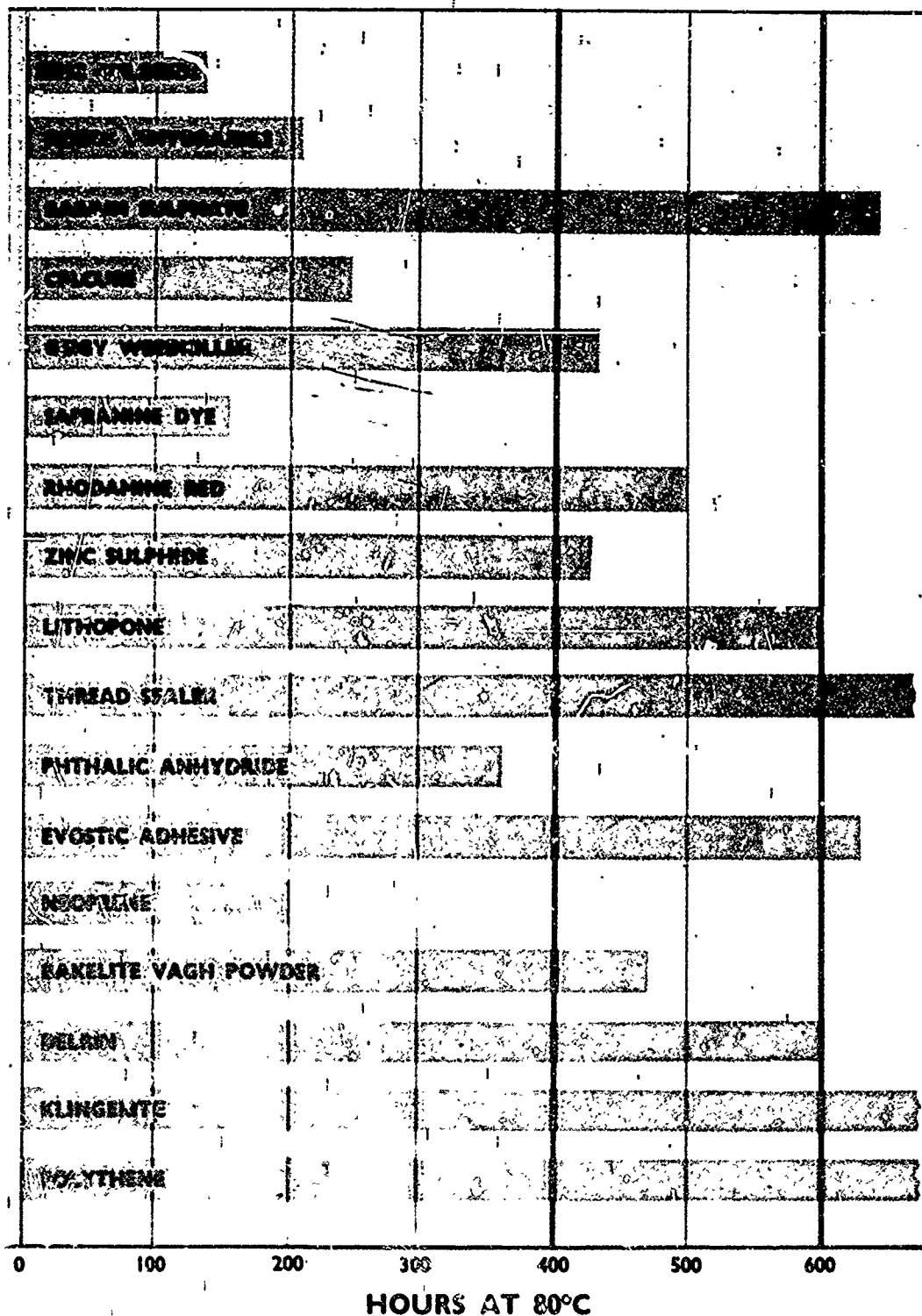
FIG. 8

SILVERED VESSEL TEST APPARATUS

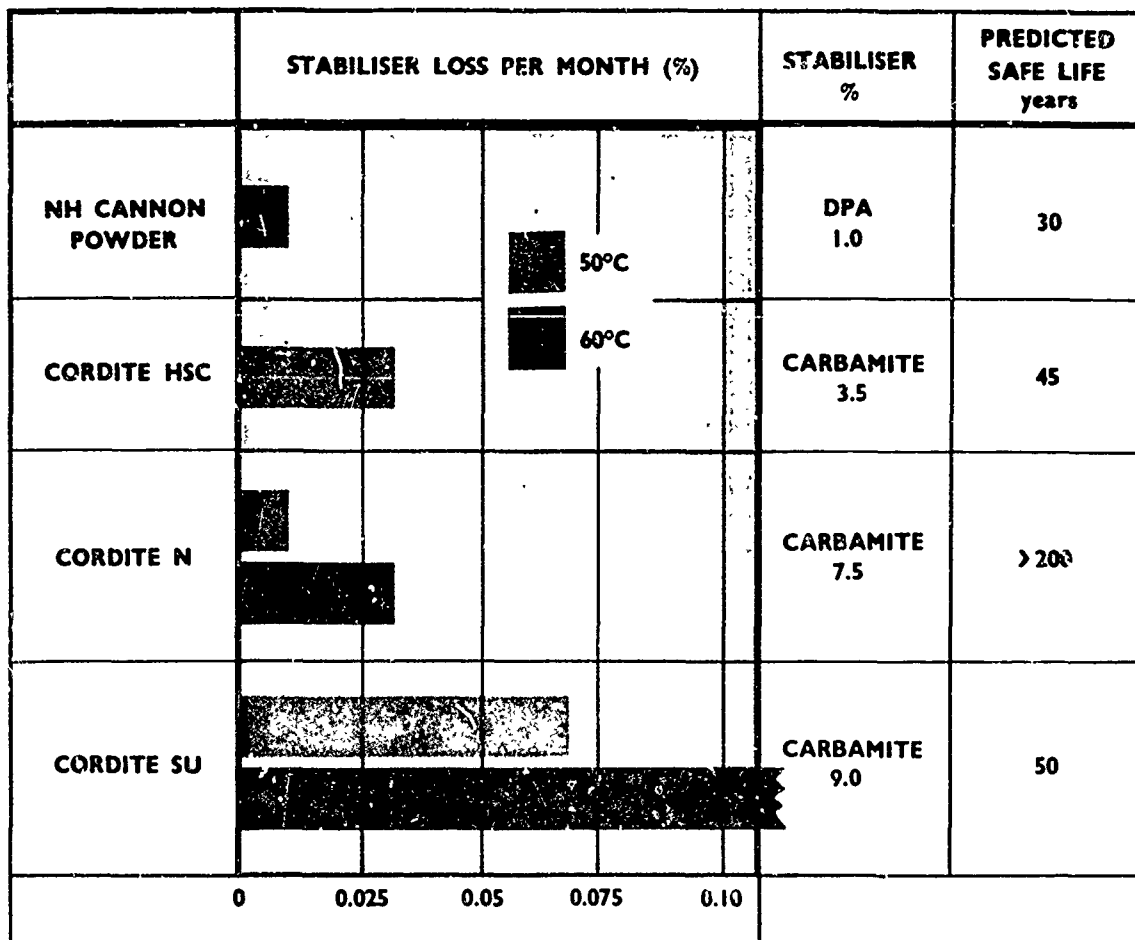


SILVERED VESSEL TEST - RESULTS

PROPELLANT F527/327 (MK. I SUBSTITUTE)
+ 5% ADDITIONS

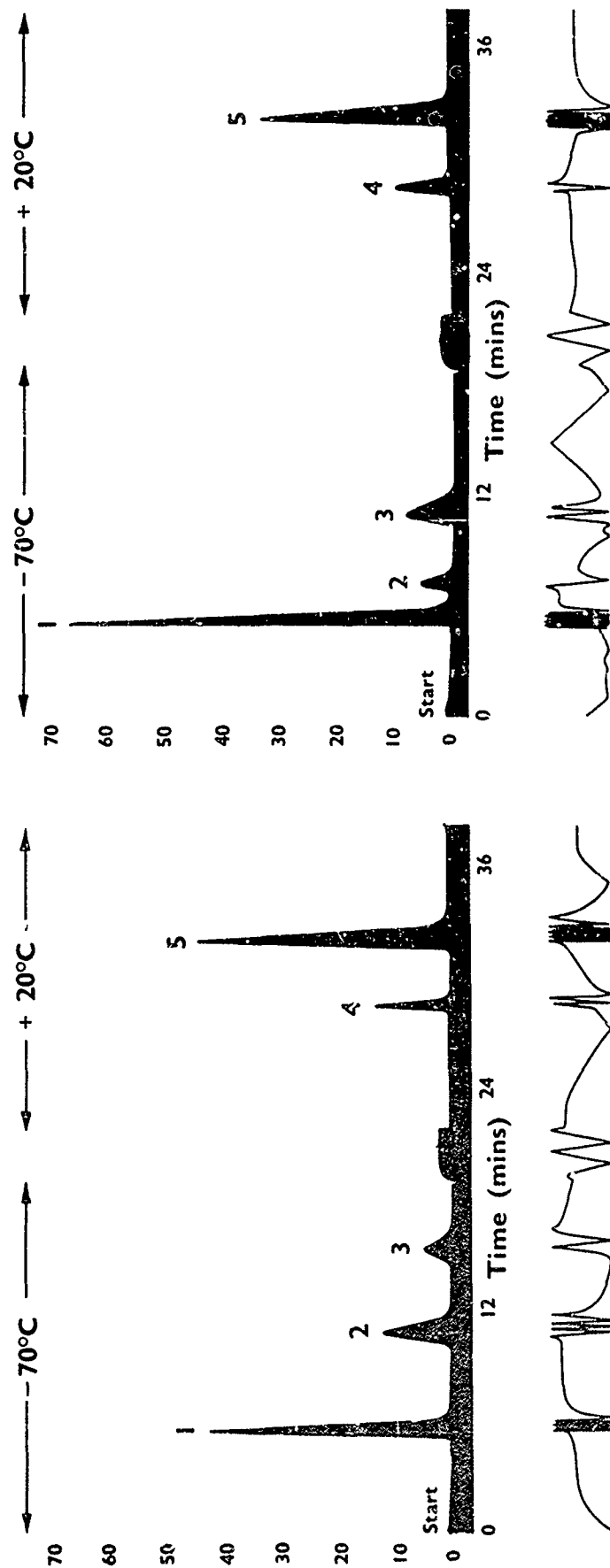


STABILISER CONSUMPTION TRIALS



		NC	NG	Picrite	DNT
NH	Single base	86	-	-	10
HSC	Double base	49.5	47	-	-
N	Triple base	19	18.7	55	-
SU	Double base	49.5	41.5	-	-

DETERMINATION OF GASES EVOLVED FROM STORED PROPELLANTS



Analysis of gas mixture from propellant heated in vacuum.
 Components: 1 : N_2 2 : CO 3 : NO 4 : CO_2 5 : N_2O
 Porapak Q (80-100 mesh) 4.5 m x 6 mm at -70°C and +20°C.
 Helium 30 ml/min. Bridge current 210 mA

Analysis of gas mixture from propellant heated with added oxygen.
 Components: 1 : N_2 2 : O_2 3 : CO 4 : CO_2 5 : N_2O
 Porapak Q (80-100 mesh) 4.5 m x 6 mm at -70°C and +20°C
 Helium 30 ml/min. Bridge current 210 mA

FIG. 12

EFFECT OF PROPELLANT VAPOURS ON THERMOPLASTICS AND RUBBERS

DEGRADATION AFTER EXPOSURE AT 60°C FOR ONE YEAR

None to slight Moderate Severe

POLYSTYRENE	NH,NQ,HUK		
ABS	NH		NQ
STYRENE-ACRYLONITRILE	NH		NQ
POLYPROPYLENE	NH	NQ	
NYLON 66	NH	NQ,HUK	
POLYSULPHONE		NQ	
POLYCARBONATE	NH		NQ
POLYACETAL	NH		
PVC			

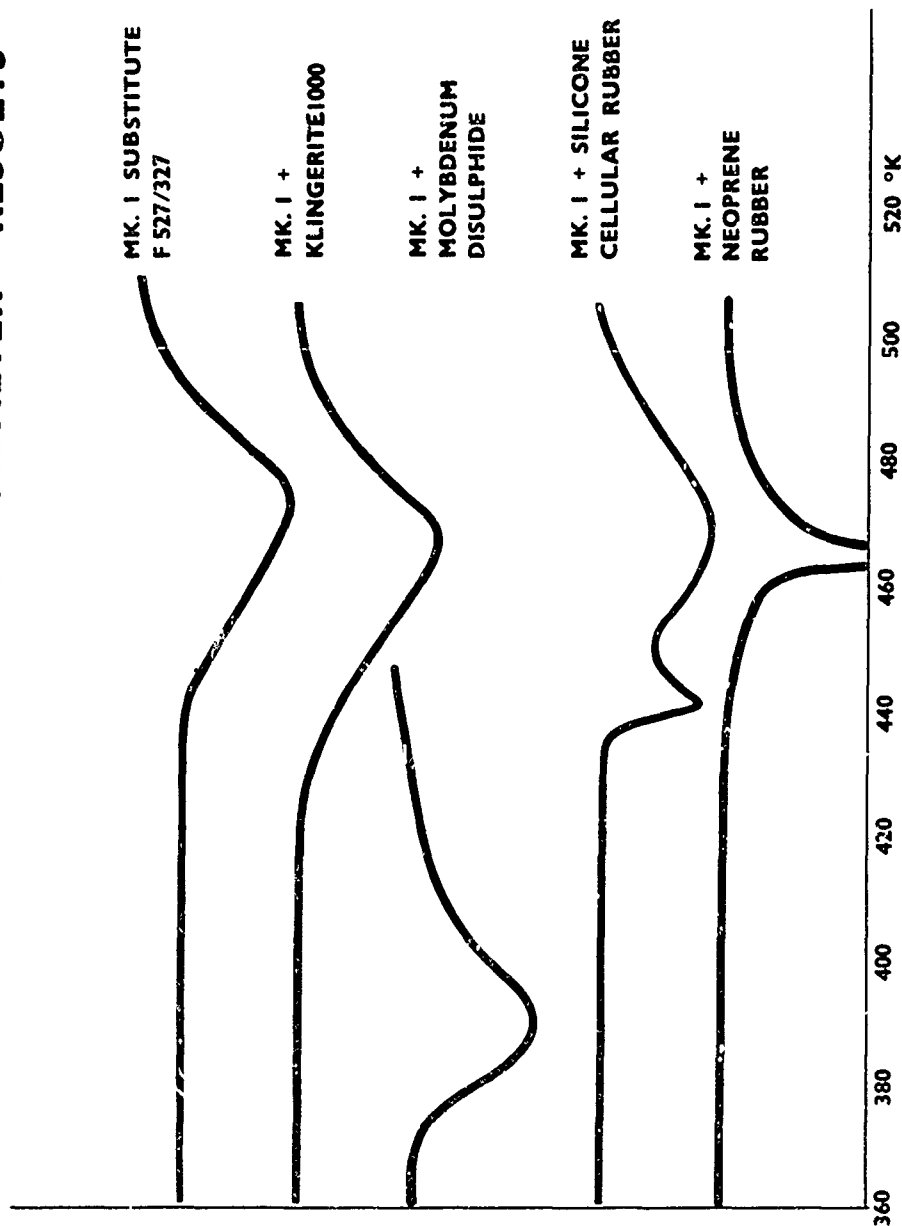
POLYMERS

NATURAL	NH	NQ,HUK	
NITRILE		NH,NQ,HUK	
NEOPRENE		NH,HUK	
BUTYL		NH,NQ,HUK	
SILICONE		NQ	

RUBBERS

NH - Single base NQ - Double base, 20% NG HUK - Double base, 43% NG

DIFFERENTIAL SCANNING CALORIMETER - RESULTS



SAMPLE - 4 + 4 mg. RANGE - 16 SCAN - 8°/MIN. CHART - 1 IN/MIN.

FIG. 14